Vincenza Tornatore et al.: European Sessions and Datum Definitions, IVS 2012 General Meeting Proceedings, p.271–275
http://ivscc.gsfc.nasa.gov/publications/gm2012/tornatore.pdf

European Sessions and Datum Definitions

Vincenza Tornatore [1], Hana Krásná (neé Spicakova) [2], Damiano Triglione [1]

[1)] *Politecnico di Milano, DIIAR*

[2)] *Vienna University of Technology, Institute of Geodesy and Geophysics*

Contact author: Vincenza Tornatore, e-mail: vincenza.tornatore@polimi.it

Abstract

In this work we present some preliminary studies to assess a method to investigate the effect of the selection of different datums on the adjustment of a geodetic network on a continental scale. In particular we have considered European VLBI sessions. All the experiments since 1990 until the end of 2010 have been processed. The adjustments, session by session, have been performed two times, under the same analysis options but fixing two slightly different datums. An analysis of estimated 3D coordinates making use of the maximum eigenvalue calculated for each station and each experiment, was carried out. The stability of the results and the influence of different datum choices on the goodness of estimated coordinates have been investigated.

1. Introduction

IVS Europe sessions have been carried out regularly since the late 1980s. Several European VLBI stations have been observing in 6 to 12 sessions per year. VLBI antennas provide very accurate and stable measurements with the objective to determine crustal motions in Europe and provide a stable European reference frame. A common issue in all positioning problems, regardless of application or accuracy, is the reference frame definition, also known as datum definition. This fundamental step establishes the coordinate system that reported positions will refer to, and it is satisfied by specifying the key parameters of translation, rotation, and scale. This paper has investigated some issues concerning datum definition as applied to regional-area networks, like the European one, VLBI-based measurement. Several works have been carried out in recent years with the aim to evaluate the effect of different datum definitions on geodetic networks: e.g., the effect on global VLBI solutions [1], or on CONT02 sessions [2], or on GNSS (Global Navigation Satellite Systems) local geodetic surveys [3]. All such works found coordinate uncertainties induced by terrestrial datum point selection, but finding a method to select datum points in an objective way is still very difficult. Some authors have suggested to include all points of the network [4] or to consider point stability and geometry [5] in addition to quantity, to realize the *optimal* datum.

In this work we first describe how European session processing and datum choice (see section 2) have been carried out. Then we propose a method which makes use of the maximum eigenvalue magnitude of the variance-covariance matrix calculated for each point of the network, to investigate possible differences due to different datum definitions (see Section 3). In the last section we briefly present preliminary conclusions and propose further processing to fully exploit the capacity of the proposed method to identify what datum definitions can bring to better results for the estimate of parameters of interest.

2. European Data Processing

Currently, fourteen radio telescopes take part in the European VLBI sessions. In any specific session, only a subset of these antennas participates. Figure 1 shows the current map of European VLBI stations: nearly all stations are homogeneously distributed on the European continent. Badary is very distant and also Ny-Ålesund looks to be quite far away from the whole set of stations.

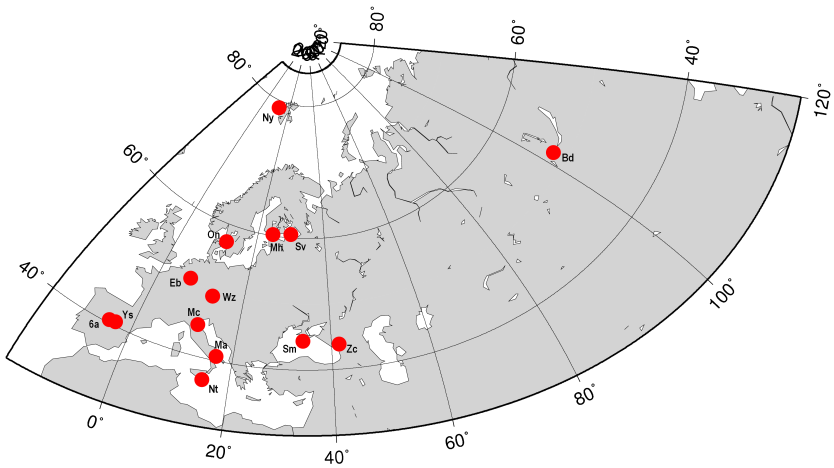

Figure 1. European VLBI stations today.

All European VLBI sessions since 1990 until the end of 2010 have been processed two times with Vienna VLBI Software (VieVS, [6]) using identical default options for each session but with two slightly different datum definitions (that we call datum1 and datum2). In the single session adjustment, the coordinates for all stations were estimated. The conditions NNT (no-net-translation) and NNR (no-net-rotation) with respect to their *a priori* values were applied to station coordinates present in the VTRF2008 catalog [7]. The changes in datum definition were:

- datum1: all five EOP parameters (x-pole, y-pole, $dUT1$, dX, and dY) were estimated
- datum2: only three EOP parameters were estimated (nutation parameters dX and dY were fixed).

3. Comparison of Different Session Adjustments using Maximum Eigenvalues of Variance-Covariance Matrix

It is well known that eigenvalue and eigenvector calculations have many useful applications in several fields of mathematics and physics. If we consider a symmetric and positive definite matrix, such as C_{XX} (the variance-covariance matrix of parameters, estimated in the adjustment of a geodetic network), its eigenvalues and the eigenvectors play an important role when we want to investigate the stochastic nature of the random vector of parameters $X \equiv (x_1, x_2, \ldots, x_n)$. Indeed, with a suitable projection of X (exploiting the eigenvectors of C_{XX}), we find a new Euclidean space, with axes $V \equiv (v_1, v_2, \ldots, v_n)$ obtained as a linear combination of $(x_1, x_2, \ldots, x_n)$, where we can measure the shape of the location-dispersion ellipsoid (see §. 2.4.3 in [8]). These considerations apply also when we study a submatrix, meaning that we extract from the whole C_{XX} only the values related to the three geometric parameters that describe the geographical position of a station ($x_1 = x,\ x_2 = y,\ x_3 = z$), leading to a small matrix with size 3x3. According to the theory, the square roots of the eigenvalues of each 3x3 covariance matrix are the lengths of the principal axes of its error ellipsoid and hence the standard deviations of the components along the direction of the principal axes (v_1, v_2, v_3). The largest eigenvalue (in magnitude) corresponds to the maximum variance achievable with a projection in the direction of the first eigenvector (the direction of the highest variation).

For each processed European experiment and each involved VLBI station, the maximum eigenvalue magnitude (from now on, named maximum eigenvalue) has been calculated for each station on the correspondent extracted (3x3) variance-covariance matrix of the three coordinates x, y, z. In Figure 2 the values of these maxima are represented in a grey value scale for each Europe experiment (rows) and for each station (columns) that observed during each experiment.

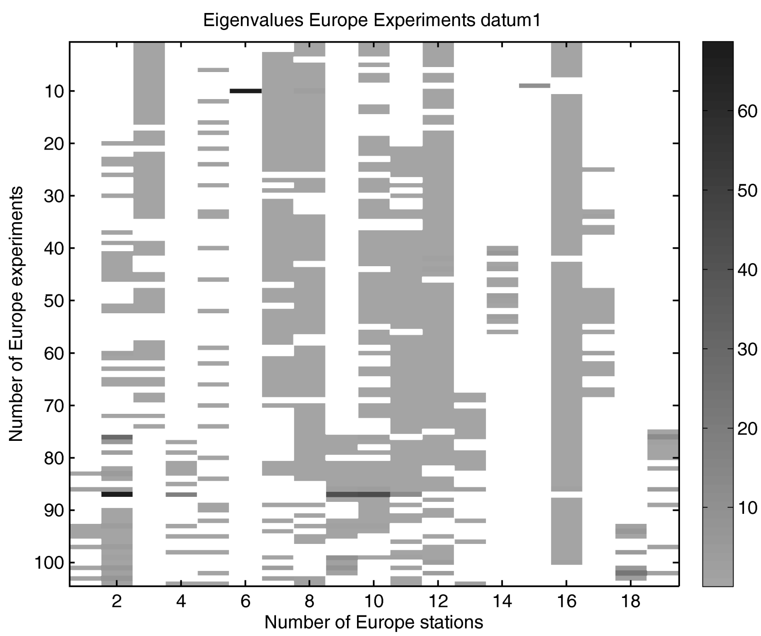

Figure 2. Maximum eigenvalue for each station (x-axis) and each experiment (y-axis) using datum1. The order of the stations is: 1 - Badary, 2 - Crimea, 3 - DSS65, 4 - DSS65A, 5 - Effelsberg, 6 - Karlsburg, 7 - Matera, 8 - Medicina, 9 - Metsähovi, 10 - Noto, 11 - Ny-Ålesund, 12 - Onsala60, 13 - Svetloe, 14 - Tigowtzl, 15 - Toulouse, 16 - Wettzell, 17 - Yebes, 18 - Yebes40, and 19 - Zelenchukskaya.

The shown values, obtained for data processed using datum1, are almost the same as those obtained for datum2 (whose values are not shown). In fact only slight differences are present among the results obtained for the two datums, and they are not perceptible by eye. The differences between the square root of each maximum eigenvalue calculated respectively for datum1 and datum2 have also been computed, after the removal of a few outliers. A mean of the differences equal to -0.0002 cm with a standard deviation of 0.0016 cm was found.

It is worth noting that looking at Figure 2 quickly identifies which experiments and which stations had very high maximum eigenvalues with respect to the others, showing clearly when and where there is a problem in the experiments. For instance the 87th experiment (08JAN21XA) has an anomalous behavior for stations number 2, 9 and 10, respectively Crimea, Metsähovi, and Noto. This led us to make a deeper investigation of the processing, correlation, and observations carried out for such experiments and stations. The analysis report publicly available in the IVS webpage states that only 16.4% of the original scheduled observations in the session 08JAN21XA were carried out and were recoverable at only five of the seven scheduled stations. Then the 10th experiment (92JUL07X_) had a high eigenvalue for station number 6 (Karlsburg). This case can be explained by considering that Karlsburg is a mobile station that observed only for that experiment. Finally the 76th experiment (06MAR21XA) had a high value for the second station Crimea. In this session observations at station Ny-Ålesund were not correlated, and only 69% of all scheduled observations could be used in the analysis.

4. Conclusions and Further Developments

In this work we have started to investigate a method making use of maximum eigenvalue determination of the variance-covariance matrix C_{XX} for checking possible disagreements in station coordinate estimates due to different datum choices. Even if in our examples the deviations due to the two selected datums are negligible, the method shows great potential. The very small differences we have found using datum1 and datum2 can be explained considering that our datum choice was in both cases a little *overconstrained* for the network we have examined. This suggests addressing further Europe experiment processing using different datum choices - for example using NNT and NNR condition only on a few stations with a stable history or with a good geometric distribution.

Furthermore the method has been also shown to be very useful for very rapidly checking the behavior of a large amount of data. We processed 104 experiments with a total set of 19 stations. We could immediately check, just by looking at one figure, that the whole set of data has a very good performance. Then it was also immediately possible to recognize the experiments and stations showing high maximum eigenvalues (and therefore high variances); for our processing these appeared very seldom. The check on original experiments where such cases occurred confirmed that the anomalous behaviors we had identified on the plot had a justifiable reason to be there.

Acknowledgements

We are grateful to the International VLBI Service for Geodesy and Astrometry (IVS) for coordinating the EUROPE campaigns and providing the data. V. Tornatore wishes to thank MIUR (Ministry of Education of University and Research) for supporting the work in the framework of the PRIN (Project of considerable National Interest, 2008) “Il nuovo di sistema di riferimento geodetico italiano: monitoraggio continuo e applicazioni alla gestione e al controllo del territorio”, National coordinator prof. F. Sansó. Hana Krásná works within FWF-Project P23143 “Integrated VLBI”.

References

[1] R. Heinkelmann, J. Böhm, H. Schuh, Effects of Geodetic Datum Definition on the Celestial and Terrestrial Reference Frames determined by VLBI, 18th Working Meeting on European VLBI for Geodesy and Astrometry (EVGA) Proceedings, TU Wien 2007, Eds. J. Böhm, A. Pany, H. Schuh, Wien, ISSN 1811-8380, pp. 88-92

[2] H. Kutterer, Reliability Measures for Geodetic VLBI Products. In: International VLBI Service for Geodesy and Astrometry 2004 General Meeting Proceedings. D. Behrend and K.D. Baver (eds) NASA/CP-2004-212255, pp. 301-305

[3] R.S. Radovanovic, N. EI-Sheimy, T. Richert, W.F. Teskey, Local datum definition and geodetic network positioning using global navigation satellite systems, Journal of Geodesy, Vol. 78: pp. 283–294, 2012

[4] G. Even-Tzur, Datum definition and its influence on the reliability of geodetic networks, Zeitschrift für Vermessungswesen 131. Jg.2/2006, pp. 87-95, 2006

[5] B.H. Papo, Datum accuracy and its dependence on network geometry, Geod. Kartogr., Springer Berlin, pp. 379-386, 2003

[6] J. Böhm, S. Böhm, T. Nilsson, A. Pany, L. Plank, H. Spicakova, K. Teke, and H. Schuh, The new Vienna VLBI software, in *IAG Scientific Assembly 2009*, IAG Symposia vol 136, S. Kenyon, M. C. Pacino, and U. Marti, Eds., Springer, Buenos Aires, Argentina, 1007–1011, 2012, doi: 10.1007/978-3-642-20338-1_126

[7] Böckmann, S., T. Artz, A. Nothnagel, VLBI terrestrial reference frame contributions to ITRF2008, Journal of Geodesy 84, pp. 201-219, 2010, doi: 10.1007/s00190-009-0357-7

[8] A. Meucci, Risk and Asset Allocation, Springer Finance, 2005, XXVI, 532 p, ISBN 978-3-540-22213-2